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Application of Evaporative Condenser in Energy Saving and Performance Improvement of Domestic Air Conditioner: A Review

Dinesh Kumar Sharma, Ramanand Sharma
MLV Textile and Engineering College, Poornima University, Bhilwara, Jaipur, India

ABSTRACT

An environmentally friendly and energy efficient method for cooling buildings in hot and dry region is Evaporative cooling. India as a multi-climates country demands a variety of cooling systems to achieve optimized energy consumption, reduce emission, and provide summer comfort condition. Many types of natural and passive methods were used for cooling buildings in traditional architecture. All of these methods have been worked based on natural ventilation. A lot of energy is consumed in operation of air conditioner using air cooled condenser as well as lot of water is wasted in water cooled condensers. So with the help of evaporative condenser, performance of refrigerating system can be increased as well as it reduces the requirement of water. With the use of evaporative condensers COP of the system can be enhanced and power consumption can be reduced.

Keywords: condenser, cooling, evaporative, power, water

Corresponding Authors
E-mail: enggdnesh@gmail.com, sharma75ramanand@gmail.com

INTRODUCTION AND BACKGROUND

All refrigeration and air conditioning processes use a gas to facilitate the transfer of heat between the air-conditioned area and the outside atmosphere. This process relies on the use of a compressor to increase the pressure in the condenser section of the system which in turn allows the absorption of heat from the conditioned area. This absorbed heat and any heat generated by the compression process needs to be rapidly removed from the refrigerant to the outside, or condenser, part of the system so that the cycle of heat transfer can be repeated.

This is typically done by allowing the hot refrigerant to circulate through a series of tubes exposed to a fan. This method of cooling or condensation of the refrigerant is not particularly efficient, particularly in large commercial systems. This lack of efficiency becomes pronounced when the ambient, or outside, temperature rises above 37 degrees Celsius. In these conditions, a conventional air-cooled system may lose up to 25% of its operational efficiency. The evaporative condenser is a far more efficient condensation mechanism in larger systems losing only a fraction of its effective capacity in all ambient conditions.

The evaporative condenser system typically consists of a series of pipes or tubes that carry the hot refrigerant gas. These tubes are simultaneously exposed to a spray of water and fan facilitated airflow. A portion of the water flowing over the gas filled tubes evaporates due to a combination of being heated by the tubes and the flow of air. This evaporation is the mechanism that allows the rapid cooling of the refrigerant gas which is then pumped back into the building to resume the air conditioning process. The remaining water is then collected and re-circulated over the condenser coils.

LITERATURE SURVEY

In the past two decades, extensive studies of evaporative cooling systems that include direct and indirect evaporative cooling equipments have been conducted by Shahram Delfani et al [4]. The main objective of these researches was to determine the energy saving potential of the evaporative cooling technology applied to residential and office buildings.

The results reported show significant energy savings in the arid and semiarid regions Goswami et al. [2] employed an evaporative cooling on existing 2.5 ton air conditioning system by using media pad. They put four media pad around condenser and inject water from the top by a small water pump. They reported the electric energy saving of 20% for the retrofitted system when ambient air temperature was 34°C. Hajidavalloo [1] investigated the effect of evaporative cooling of window-air-conditioner by injecting water directly on the condenser and reported 10% reduction in power consumption.

Although the problem in air conditioner performance in very hot weather condition have been reported for long time but there is little work to address the problem and offer appropriate solution. There are many questions about the ways of applying evaporative cooling in the system and also the amount of expected improvement in COP after retrofitting especially in very hot weather condition.

In order to specify the best arrangement and optimum design of evaporative cooling in the residential air conditioner, much works are required. In this work an experimental investigation was performed to evaluate the application of media pad evaporative cooling system in a 1.5 ton window air-conditioning system in very hot weather condition.

E. Hajidavalloo*, H.Eghtedari [3] conducted an experimental study on a split type air conditioner and showed that experimental tests showed that power consumption and performance of evaporative cooled air condenser improved significantly compared to the air-cooled condenser and the improvements are increased as ambient temperature increases.

It was found that increasing ambient air temperature decreases the coefficient of performance of air-cooled condenser considerably but it has much less adverse effect on the performance of evaporative cooled air condenser. Power consumption can be decreased up to 20% and total performance can be improved around 50%.

The Condensing Process

Superheated refrigerant vapor enters the condenser, where it loses heat by passing close (i.e. the thickness of a tube wall) to a coolant fluid. The coolant may be air, water or other fluids. The refrigerant vapor is first cooled to its saturation temperature (dependent on the pressure of the vapor) at which point condensation begins. As it condenses to a liquid at constant temperature, latent heat is released. Only when the condensation process is finished, does the refrigerant temperature start to fall once more.

This further cooling below the condensing temperature is called subcooling and most commonly occurs in the liquid line. The condensing process is illustrated in Figure 1. Figures 2 and 3 show how the temperatures change for refrigerant and for coolant [7].

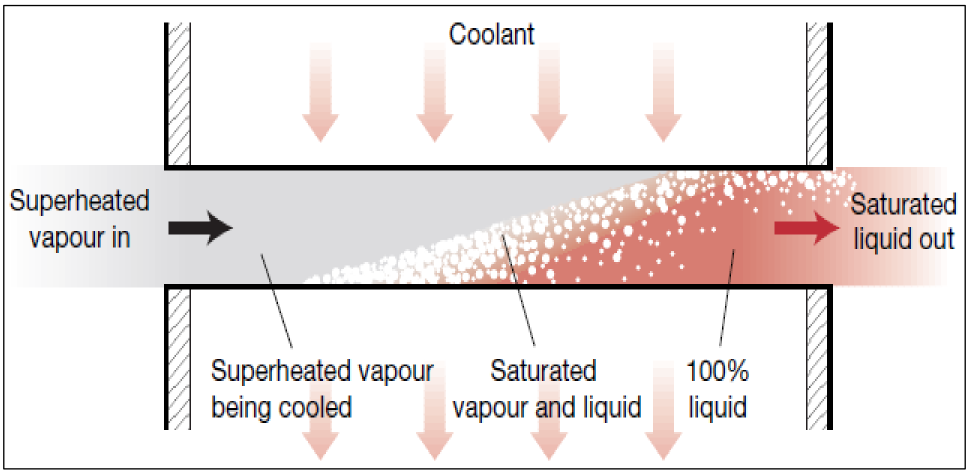

Fig. 1. *Refrigerant flow in a condenser tube [7].*

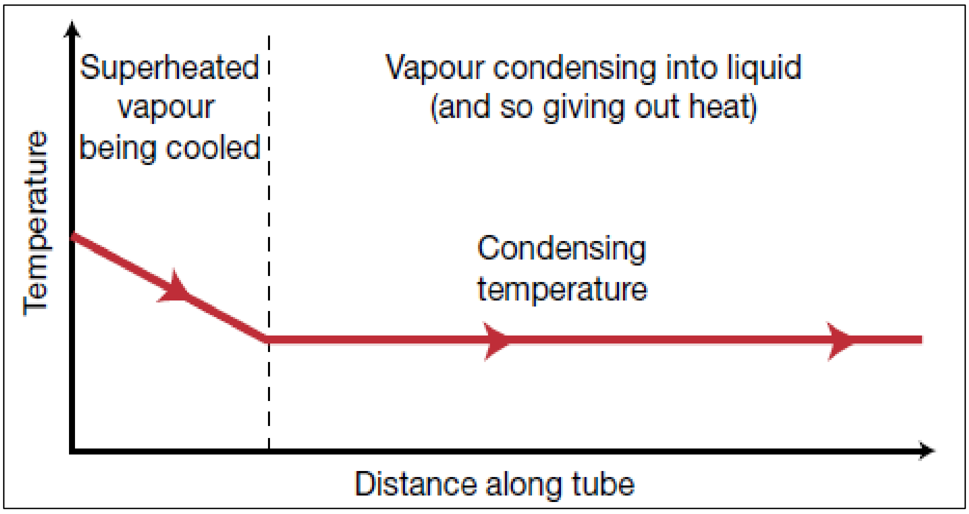

Fig. 2. *Temperature graph of the refrigerant as it flows along the condenser [7].*

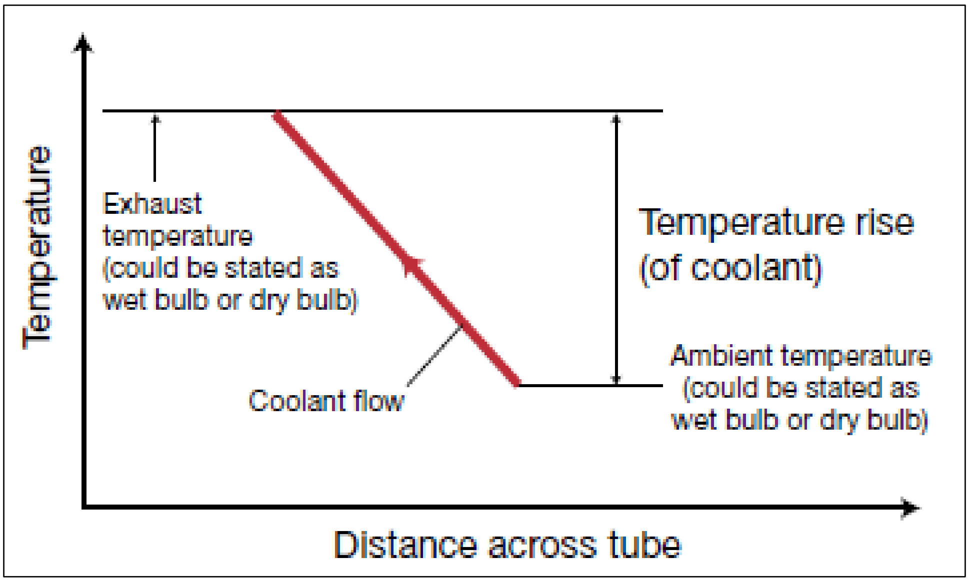

Fig. 3. *Parameters affecting performance of condenser.*

There are several factors which affect the performance of air conditioner like

(i) Condenser pressure
(ii) Ambient temperature
(iii)Scaling
(iv)Variable frequency drive (VFD)
(v) Approach temperature difference

Effect of Condenser Pressure

Figure 4 shows the effect of evaporator and condenser temperatures on COP of the SSS (Simple Saturated System) cycle. As expected, for a given condenser temperature the COP increases rapidly with evaporator temperature, particularly at low condensing temperatures. For a given evaporator temperature, the COP decreases as condenser temperature increases. However, the effect of condenser temperature becomes marginal at low evaporator temperatures.

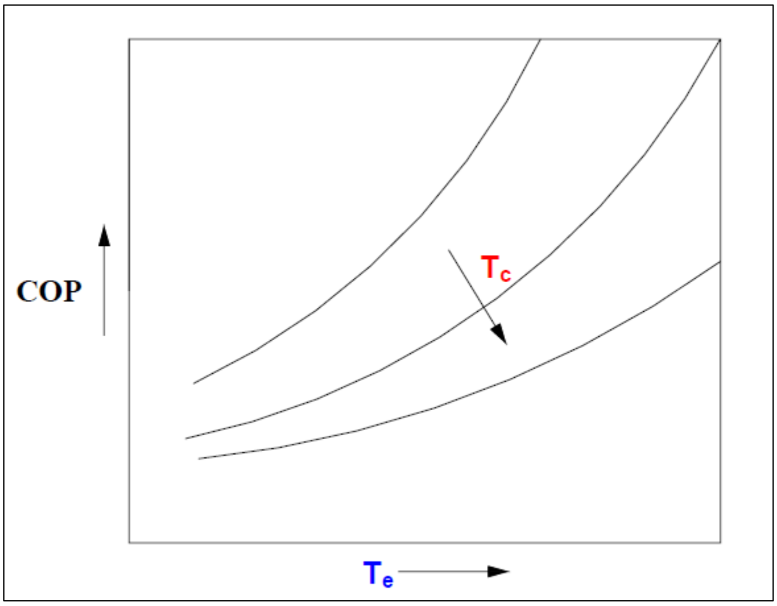

Fig. 4. *Effect of evaporator and condenser temperature on COP of VCRS.*

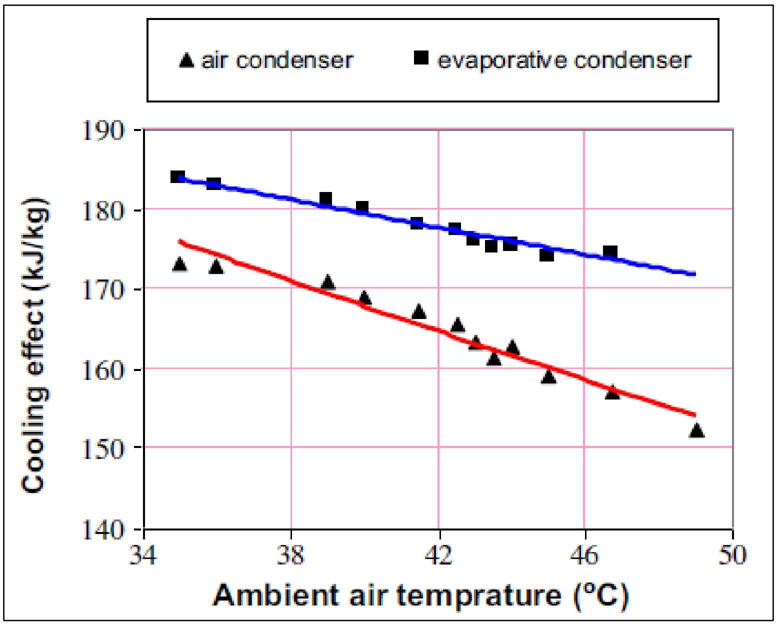

Fig. 5. *Cooling effect variation at different ambient air temperature [3].*

Effect of Ambient Temperature

Many tests at different ambient conditions, ranging from 35.0 to 49.0°C, were performed in order to have better understanding of the system behavior. Figure 5 compares the variation of refrigeration effect for two condensers in terms of ambient air temperature. It can be seen that the performance of the evaporatively cooled condenser is much better than the air- cooled condenser and the improvement is increased as ambient temperature increases. Figure 6 compares the variation of compressor work for two condensers in terms of ambient air temperature. As seen, with increasing air temperature compressor work is increased and there is considerable difference between two condensers performance. Figure 7 shows variation of COP versus ambient air temperature for two type condensers. As the experimental results show the difference between two curves is very large and it increases as ambient air temperature increases [3].

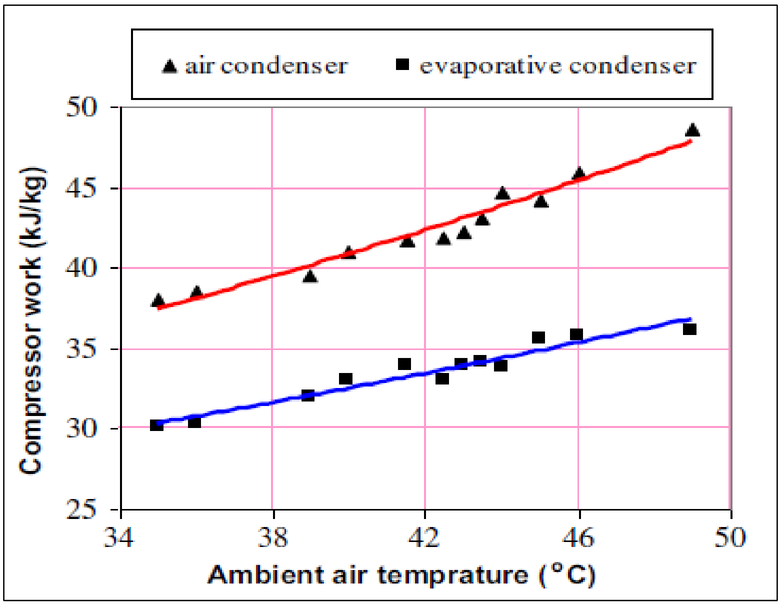

Fig. 6. *Compressor work variation at different ambient air temperature [3].*

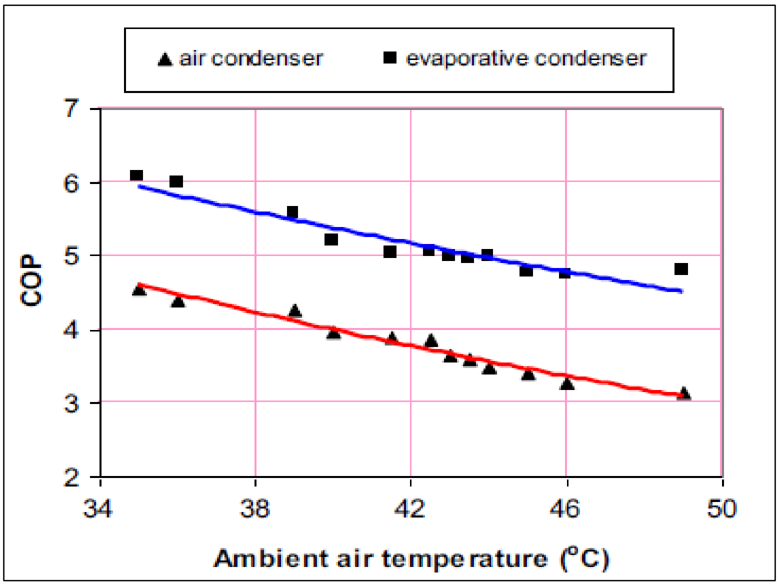

Fig. 7. *COP variation at different ambient air temperature [3].*

Effect of Scaling

Due to presence of water in evaporative condenser, they get affected with the problem of scaling. Scale formation on condenser surface affects the heat transfer capacity of condenser, finally heat dissipation rate from the condenser to atmosphere is reduced and ultimately power consumption and COP of system is reduced. Even minimal amounts of scale on the condensing coil surface will affect the performance of evaporative condensers. Figure 8 illustrates the impact of scale build-up on condenser performance. With only 1/32" thick scale, the evaporative condenser performance is robbed of 27% of its heat transfer capability. As scale thickness increases, capacity losses increase significantly [5].

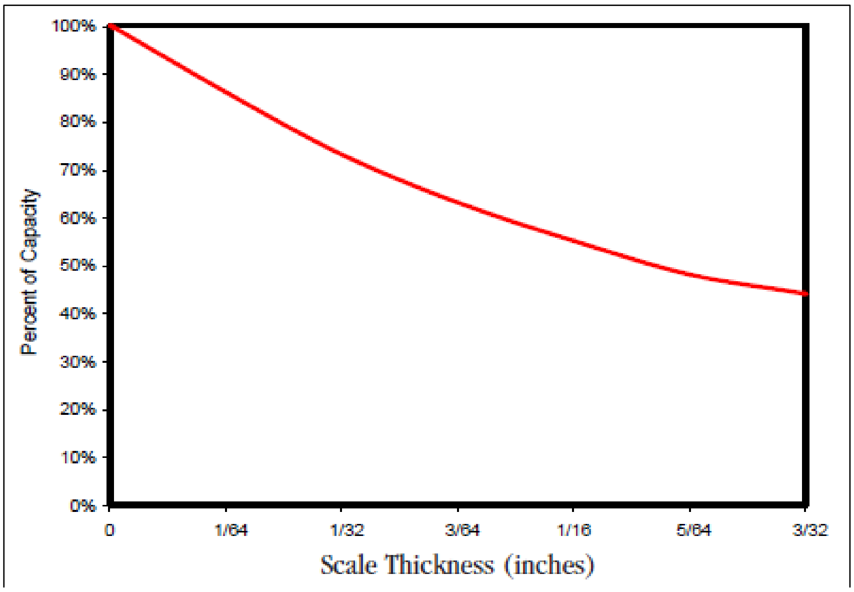

Fig. 8. *Condenser performance with Scale [5].*

Variable Frequency Drives

By applying variable frequency drives for evaporative condenser fan operation, can deliver refrigeration system energy efficiency improvements as well as collateral benefits. The energy benefit of applying variable frequency drives for condenser fans increases as the size of the condensers increase.

A collateral operational benefit of variable speed fan control is minimal fluctuation in system head pressure because the condenser fan motor drive continually modulates the condenser capacity to maintain head pressure. Steady head pressures are a key factor in stabilizing system operation. Variable frequency drives also reduce (or eliminate) the starting and stopping of fan motors. Frequently starting and stopping fan motors (as required in strategies that use single and two-speed fans) increases wear and tear on fan belts (if equipped), bearings, shafts, and fan blades. Cycling electric motors on and off also shortens motor life. Operating condenser fans at reduced speed also decreases drift losses from the condensers [6].

Approach Temperature Difference

In order to transfer heat from the refrigerant to the coolant, there must be a temperature difference between the two, and this is called the approach temperature difference (ATD), illustrated in Figure 9. This must be large enough to provide the heat flow needed to achieve the required system capacity. However, for maximum efficiency, the ATD should be minimized, as this will reduce the temperature lift of the system.

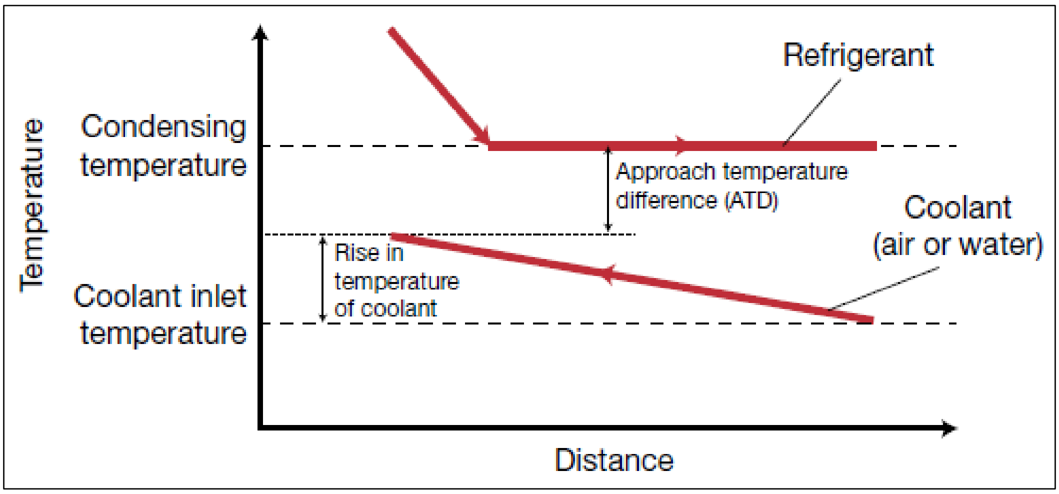

Fig. 9. *Diagram showing approach temperature difference between refrigerant and coolant in a condenser [7].*

The inlet temperature of the coolant is usually not controllable (e.g. ambient air temperature, or temperature of water available) but the coolant should be selected to have as low a temperature as possible. The lower the coolant temperature, for a given ATD, the more efficient the system will be. The coolant temperature naturally rises as it cools the refrigerant – the magnitude of this temperature rise depending on the flow rate and the type of coolant used. For maximum efficiency, this temperature rise should be kept low, as that means the condensing temperature can also be lower. However, the higher flow rates required would need larger fans and/or pumps, which also consume energy. As ever with refrigeration systems, a sensible balance (i.e. optimum design) must be found between conflicting requirements [7].

CONCLUSION

The evaporative condenser utilizes both ambient air and the evaporation of water to remove heat from the refrigerant vapor flowing inside the coils of the unit. Ambient air is blown up over the condenser into water sprayed down from a sparge system mounted above the condenser. The water absorbs heat from the refrigerant and evaporates into steam at the prevailing wet bulb temperature. This steam is rapidly removed by the circulating air. This improves the cooling effect because the surface temperature of the condenser pipes approaches wet bulb temperature, increasing the efficiency of the unit. A continuous make-up of the circulated water is required to replenish that lost by evaporation. The big advantage of evaporative condensers over shell and tube condensers and cooling towers is that the circulating water pump is much smaller. However, an evaporative condenser needs to be placed close to the compressor, to avoid long runs of refrigerant pipe work.

Generally air-cooled and water cooled condensers are used in residential and commercial applications. But due to association of lower performance with air cooled condenser and availability of water and fouling problems with water cooled condensers generates the idea of new type of condenser- evaporative condense, which is the combination of water cooled and air cooled condensers.

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